MYCOTAXON

*Volume 112, pp. 173–187* *April–June 2010*

# Three new species of the genus *Erysiphe* (*Ascomycota, Erysiphales*) on legumes and some new combinations

Uwe Braun

*uwe.braun@botanik.uni-halle.de*
*Martin-Luther-Universität, Institut für Biologie*
*Bereich Geobotanik und Botanischer Garten*
*Herbarium, Neuwerk 21, D-06099 Halle (Saale), Germany*

Julia Kruse

*Julia.Kruse1@gmx.de*
*Nobelring 10, Zi. 217*
*D-30627 Hannover, Germany*

Silvia M. Wolcan

*swolcan@speedy.com.ar*
*Comisión de Investigaciones Científicas BA, CIDEFI*
*Facultad de Ciencias Agrarias y Forestales, UNLP*
*60 y 119, (1900), La Plata, Buenos Aires, Argentina*

Mónica Murace

*mmurace@gmail.com*
*Cátedra de Protección Forestal*
*Facultad de Ciencias Agrarias y Forestales, UNLP*
*60 y 119, (1900), La Plata, Buenos Aires, Argentina*

**Abstract** — The new combination *Erysiphe trifoliorum* (= *Erysiphe trifolii*) is introduced, and its former varieties *E. trifolii* var. *intermedia* and var. *desmanthi* are reassessed and raised to species rank. Furthermore, three new species of the genus *Erysiphe*, viz. *Erysiphe baptisiae* on *Baptisia australis* in Europe, *E. baptisiicola* on *Baptisia* spp. in North America and *E. sesbaniae* on *Sesbania punicea* in Argentina, South America, are described, illustrated and discussed. A key to species of *Erysiphe* on legumes allied to the new species is provided.

**Key words** — *Erysiphaceae*, *E. desmanthi*, *E. intermedia*, *Fabaceae*, lectotype

## Introduction

Powdery mildews (*Erysiphales*) of the genus *Erysiphe* DC. on legumes represent one of the taxonomically most complicated groups within this genus. There

is a wide range of species on legumes with unbranched, irregularly branched to dichotomously branched chasmothecial appendages that are intermediate between those of the classical genera, *Erysiphe* and *Microsphaera* Lév. (Braun 1987, Heluta 1998), now treated as sections of *Erysiphe* emend. U. Braun & S. Takam. (Braun & Takamatsu 2000). The existence of such intermediate taxa questioned the justification of the classical discrimination between *Erysiphe* and *Microsphaera*. Phylogenetic hypotheses based on molecular sequence analyses (Saenz & Taylor 1999, Mori et al. 2000) supported the assumption that a separation of *Erysiphe* and *Microsphaera* is not tenable, which led to the merging of the two genera (Braun & Takamatsu 2000, Braun et al. 2002). In this work, the nomenclature and taxonomy of the *Erysiphe trifolii* complex are reassessed and revised. Furthermore, three new species on legumes belonging to the morphologically intermediate taxa described above have been found. They are described and discussed, and a key to them and allied species is provided.

## Materials and methods

Fruiting bodies were mounted in distilled water and examined for description by means of standard light microscopy (Olympus BX 50, Hamburg, Germany) using oil immersion (bright field and phase contrast), but without any staining. Anamorphs were mounted in lactic acid, gently heated and stained with cotton blue. Thirty measurements (× 1000 magnification) of conidia and other structures were made. The extremes are given in parentheses. The collections examined are deposited in the herbaria BPI, HAL, LPS and STR (abbreviations according to Holmgren et al. 1990).

## Taxonomy

### 1. Reassessment of nomenclature and taxonomy of *Erysiphe trifolii*

*Erysiphe trifolii* is a common and widespread powdery mildew on a wide range of legumes, and it is well characterized and distinguished from *E. pisi* DC. by its very long, non-mycelioid chasmothecial appendages (Braun 1987, 1995; Braun & Takamatsu 2000). The appendages are usually unbranched, but in fully mature samples some apices may become 1–2(–3) times dichotomously branched with straight ultimate tips, which renders this species a morphologically intermediate taxon between the former classical concepts of *Erysiphe* (now *Erysiphe* sect. *Erysiphe*) and *Microsphaera* (now *Erysiphe* sect. *Microsphaera* (Lév.) U. Braun & Shishkoff). Recently, original material of powdery mildew species described by Wallroth (1819a,b) under *Alphitomorpha* Wallr. has been re-examined and considered, in some cases, for lectotypification purposes. Type material, designated below, of *Alphitomorpha trifoliorum*, a name that is older than *E. trifolii*, proved to be identical with the current concept of the latter

species, i.e. *A. trifoliorum* has priority and must be reallocated to *Erysiphe*. The epithets "*trifoliorum*" and "*trifolii*" are not confusable. Also, the former concept of *E. trifolii* is morphologically heterogeneous and includes several taxa that have to be recognized as distinct from *E. trifolii*. Two morphologically well-discriminated varieties have been previously described (Braun 1984, 1985, 1987, 1995), and these are herein, in a first step, raised to species rank. *E. trifolii* s. str., now *E. trifoliorum*, without its varieties is still a complex species with wide host range and considerable morphological variability. Braun (1987) listed names of various species as synonyms of *E. trifolii*, e.g. *Erysiphe robiniae* Grev. and *Microsphaera caraganae* Magnus. It is now necessary in a subsequent publication to re-examine and reassess the whole complex in a second step.

***Erysiphe trifoliorum*** (Wallr.) U. Braun, **comb. nov.**

MycoBank, MB 516541

Bas.: *Alphitomorpha trifoliorum* Wallr., Ann. Wetterauischen Ges. Gesammte Naturk. 4: 238, 1819.

= *Erysiphe trifolii* Grev., Fl. edin.: 459, 1824.

≡ *Microsphaera trifolii* (Grev.) U. Braun, Nova Hedwigia 34: 685, 1981.

**Lectotype** of *A. trifoliorum* (**designated here**): on *Trifolium medium* L. (= *T. flexuosum* Jacq.), GERMANY, without any further data, herb. Wallroth (STR).

Notes: Wallroth (1819b) introduced the name *A. trifoliorum*, i.e. he undoubtedly intended to and described a new species of powdery mildew for *Trifolium* spp. The lectotype is the only collection in Wallroth's herbarium deposited as *A. trifoliorum* [on *Trifolium medium* (= *T. flexuosum*)], i.e. a host species mentioned by Wallroth (1819b) in the original description, and we presume it is part of the original material. *A. trifoliorum* is the oldest valid name for this species. The morphological characteristics of the lectotype collection of *A. trifoliorum* agree well with those of other collections of *E. trifoliorum* on *Trifolium* spp.: Chasmothecia 90–130 µm diam., with 8–20 appendages, 2–5 times as long as the chasmothecial diam., with few septa, apex mostly simple, rarely dichotomously branched, asci 4–8, 50–70 × 25–45 µm, 3–5-spored, ascospores 19–24 × 10–14 µm.

***Erysiphe intermedia*** (U. Braun) U. Braun, **comb. et stat. nov.**

MycoBank, MB 516542

Bas.: *Microsphaera trifolii* var. *intermedia* U. Braun, Zentralbl. Mikrobiol. 140: 416, 1985.

≡ *Erysiphe trifolii* var. *intermedia* (U. Braun) U. Braun & S. Takam., Schlechtendalia 4: 15, 2000.

Holotype: on *Lupinus perennis* L., USA, Massachusetts, Mouson, Aug. 1883, A.B. Seymour, Rabenh., Fungi Eur. Exs. 3243a (HAL). Isotypes: Rabenh., Fungi Eur. Exs. 3243a. Paratypes: on *Lupinus perennis*, USA, New Jersey, Jamesburg, Jul. 1889, B.D. Halsted, Ellis & Everh., N. Amer. Fungi 2338 (FH); USA, Ohio, Toledo, 21 Jul. 1900, F.D. Kelsey, Vestergr., Micromyc. Rar. Sel. Praec. Scand. 664 (FH).

Notes: This species is confined to hosts of the genus *Lupinus* in North America and Europe. It is easily distinguishable from *E. trifoliorum* by having 0–1-septate, colorless chasmothecial appendages with a distinct tendency to turn towards one direction, as for instance in *Erysiphe astragali* DC. and *E. baeumleri* (Magnus) U. Braun & S. Takam. (Braun 1987, 1995). The appendages in *E. trifoliorum* are horizontally spread, 0–6-septate and pigmented below the septa.

***Erysiphe desmanthi*** (U. Braun) U. Braun, **comb. et stat. nov.**

MycoBank, MB 516543

Bas.: *Microsphaera trifolii* var. *desmanthi* U. Braun, Mycotaxon 19: 375, 1984.

≡ *Erysiphe trifolii* var. *desmanthi* (U. Braun) U. Braun & S. Takam., Schlechtendalia 4: 15, 2000.

Holotype: on *Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald (= *D. brachylobus* Benth.), USA, Missouri, St. Louis, Oct. 1886, herb. Trelease (FH).

Notes: *E. desmanthi* is an endemic North American species well-distinguished from *E. trifoliorum* by having much smaller, usually caulicolous chasmothecia, 70–90(–105) µm diam., and evidently verrucose appendages (Braun 1987).

## 2. A new species of *Erysiphe* on *Baptisia australis* in Europe

***Erysiphe baptisiae*** U. Braun & J. Kruse, **sp. nov.** Fig. 1

MycoBank, MB 516544

Erysiphes intermediae *similis, sed appendicibus chasmotheciorum horizontaliter effusis, cellulis basalibus conidiophorum saepe curvatis vel sinuosis.*

Etymology: derived from the host genus.

Type: GERMANY. Niedersachsen, Hannover, Herrenhausen/Leinhausen, Vinnhorster Weg, Schulbiologiezentrum, on *Baptisia australis* (L.) R. Br. (*Fabaceae*), 5 Oct. 2009, J. Kruse (HAL 2337 F, **holotype**).

Mycelium amphigenous, in grayish white patches or effuse, often covering the entire leaf surface, thin, persistent; hyphae branched, usually straight to somewhat sinuous, 3–7 µm wide, septate, hyaline, thin-walled, smooth or almost so. Appressoria solitary, 3–7 µm diam., lobed. Conidiophores arising from superficial hyphal mother cells, terminal to lateral, almost in the middle of the mother cell or toward one end, erect, straight, up to about 80 µm long (without conidia), foot-cells 15–35 × 5–8 µm, cylindrical, straight to mostly somewhat curved to distinctly sinuous, followed by 1–2 shorter cells, about 10–30 µm long. Conidia formed singly, primary conidia ellipsoid-ovoid, secondary conidia ellipsoid-cylindrical to almost doliiform, 22–35 × 12–16 µm, length/width ratio usually 1.8–2.5, ends rounded to truncate. Chasmothecia scattered to gregarious, 80–120 µm diam., subglobose; peridium cells irregularly polygonal, 10–25(–30) µm diam., walls of the cells up to about 2 µm thick. Appendages 6–15(–20), ± equatorial, flexuous, straight, curved to sinuous,

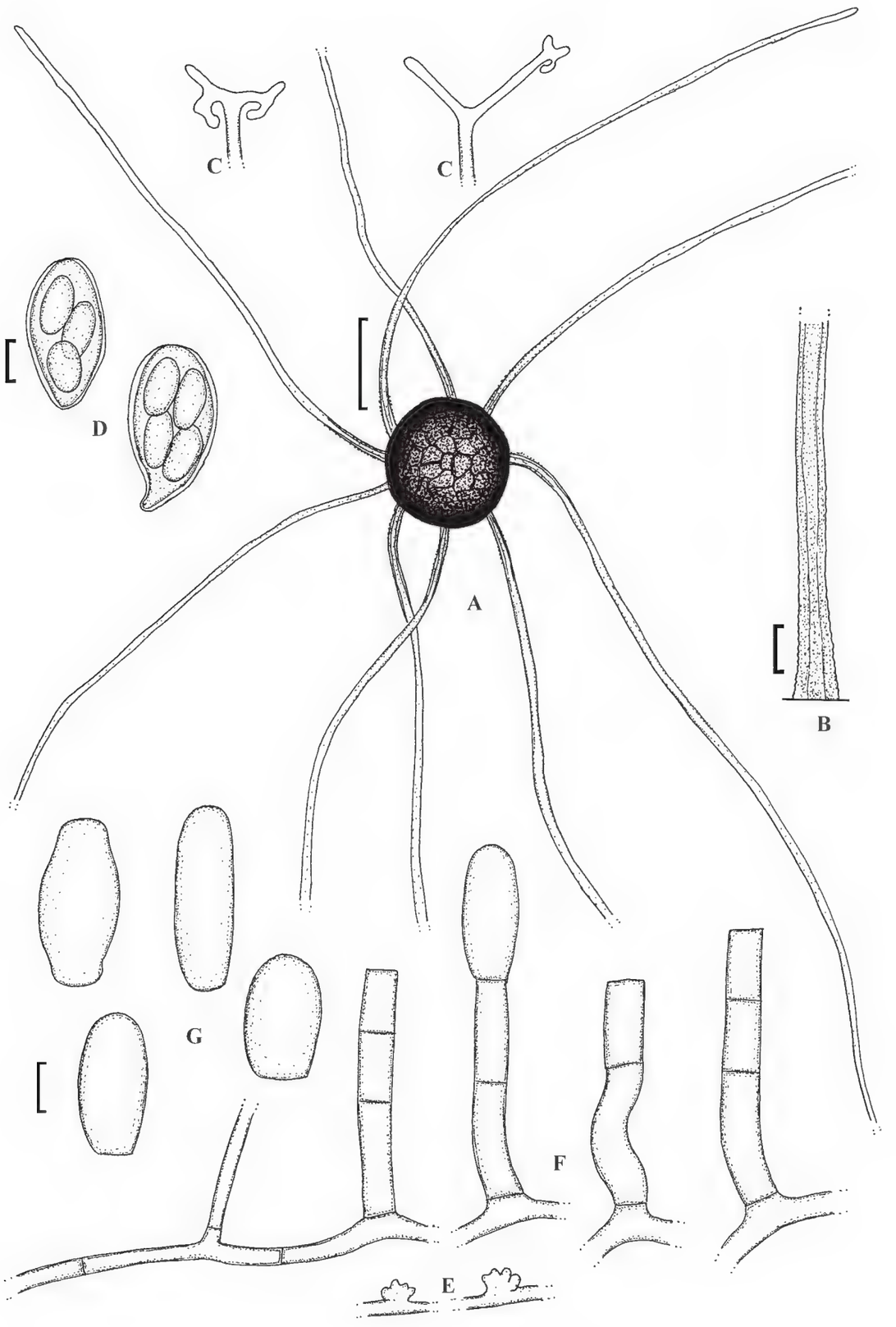


Fig. 1. *Erysiphe baptisiae* (based on type material).
A. Chasmothecium. B. Appendage. C. Branched tips of appendages (from Eliade 1990, as *Microsphaera rayssiae*). D. Asci. E. Appressoria. F. Conidiophores. G. Conidia.
Scale bars = 100 µm (A), 10 µm (B–G). U. Braun del.

more or less horizontally spread, not turning towards one direction, apex usually unbranched, rarely 1–2 times dichotomously branched in fully mature samples, ultimate tips straight to somewhat curved, 4–10 times as long as the chasmothecial diam. (up to about 800 µm long), 3–8 µm wide, width somewhat decreasing from base to top, aseptate, hyaline, thick-walled at the base, up to 3 µm, becoming gradually thinner towards the tip, verruculose towards the base, smooth above. Asci 3–8 per chasmothecium, obovoid to saccate, 45–70 × 25–35 µm, sessile to short-stalked, wall thin, up to 1.5 µm, terminal oculus indistinct, 3–5-spored, ascospores ellipsoid-ovoid, 14–23 × 10–14 µm, colorless.

Comments: European powdery mildew on *Baptisia australis* has previously been referred to as *Erysiphe rayssiae* (Mayor) U. Braun & S. Takam. [≡ *Microsphaera rayssiae* Mayor] (Mayor 1968, Eliade 1990). *Erysiphe rayssiae* on *Spartium* [*Fabaceae*, *Genisteae*] is quite distinct from *E. baptisiae* on *Baptisia* [*Fabaceae*, *Thermopsideae*] by having straight, cylindrical conidiophores and very irregularly shaped, mycelioid, strongly geniculate-sinuous chasmothecial appendages with frequently branched apices. *Erysiphe baptisiae* belongs to the *E. trifoliorum* complex, characterized by chasmothecia with very long, but usually unbranched appendages. Eliade's (1990) description agrees very well with *E. baptisiae*, but she described and illustrated the occurrence of terminally branched appendages. However, material on *Baptisia* from Romania and Switzerland was not available for re-examination. The foot-cells of the conidiophores in *E. intermedia* and *E. trifoliorum* are cylindrical, usually straight, only occasionally slightly curved or flexuous. The appendages in *E. trifoliorum* are 0–6-septate and pigmented below the septa. The long appendages in *E. intermedia* have an obvious tendency to turn towards one direction, as in *E. astragali* and *E. baeumleri*. The appendages in the latter two species are often dichotomously branched. *Erysiphe* on *Baptisia* spp. is known from North America and was previously identified as *E. polygoni* DC., *E. communis* (Wallr.) Schltdl. and *E. martii* Lév. Several collections deposited at BPI have been examined, but all of them proved to belong to another species, one described below, that is morphologically closer to *E. pisi*.

### 3. A new species of *Erysiphe* on *Baptisia* spp. in North America

***Erysiphe baptisiicola*** U. Braun, **sp. nov.** Fig. 2

MycoBank, MB 516545

Erysiphes pisi *similis, sed cellulis basalibus conidiophorum saepe curvatis vel sinuosis, conidiis angustioribus, plus minusve < 15 µm latis, appendicibus chasmotheciorum obscure pauciseptatis, parietibus basim versus incrassatis, verruculosis.*

Etymology: derived from the host genus.

Type: USA. Connecticut, Elm City Nursery, on leaves of *Baptisia australis* (*Fabaceae*), Oct. 1907, G.P. Clinton (BPI 564440, **holotype**).

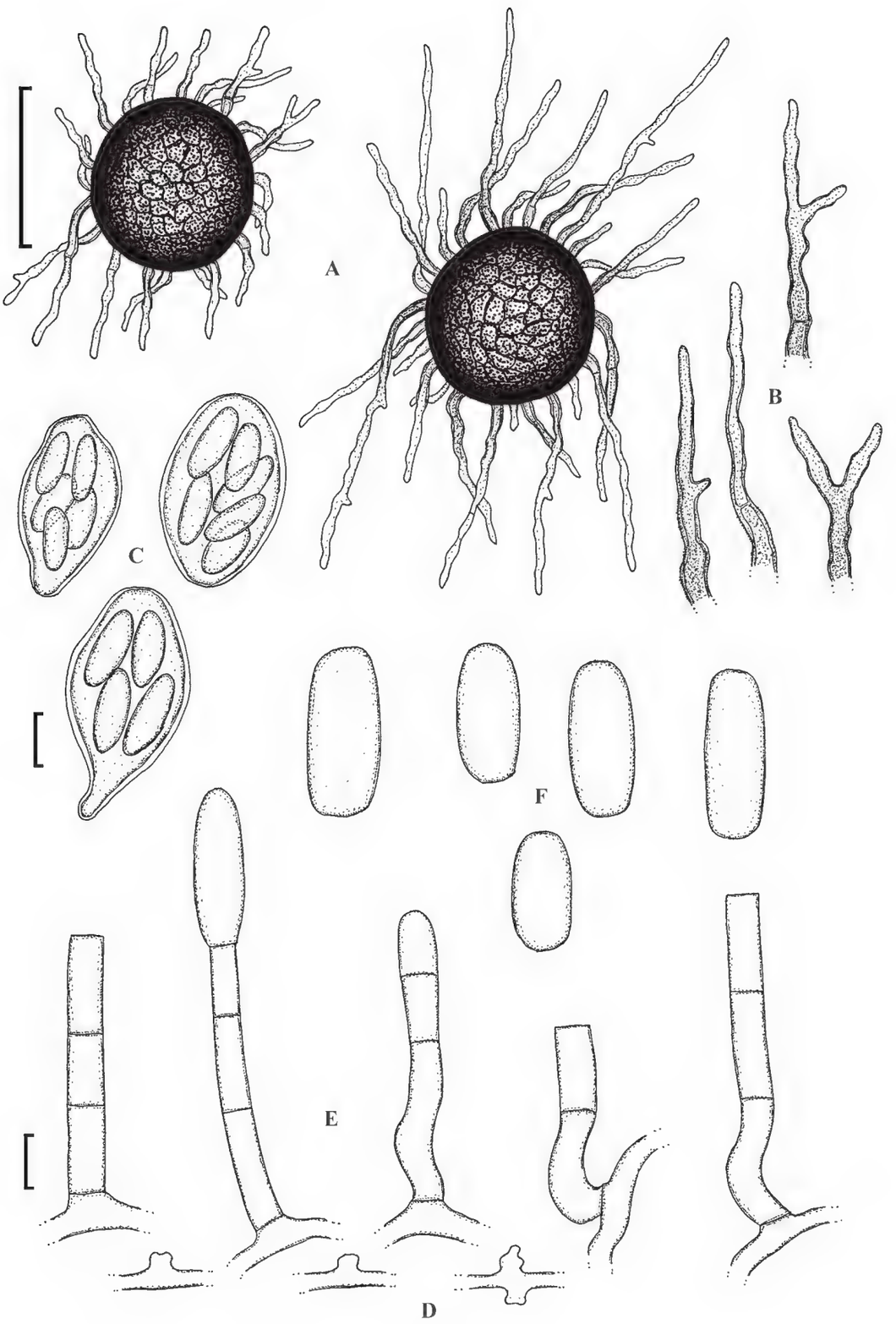


Fig. 2. *Erysiphe baptisiicola* (based on type material).
A. Chasmothecia. B. Appendages. C. Asci. D. Appressoria. E. Conidiophores. F. Conidia.
Scale bars = 100 μm (A), 10 μm (B–F). U. Braun del.

Mycelium amphigenous, forming dense, thin to thick, persistent patches or complete covers; hyphae branched at more or less right angle, straight to sinuous, 2–7 µm wide, septate, hyaline, thin-walled, smooth to verruculose. Appressoria solitary or occasionally in opposite pairs, nipple-shaped, with crenulate outline to somewhat lobed, 2–5 µm diam. Conidiophores arising from superficial hyphal mother cells, terminal to lateral, usually somewhat towards one end of the cell, erect, up to about 90 µm long (without conidia), foot-cells 15–30 × 6–9 µm, subcylindrical, straight to usually curved-sinuous, followed by 1–3 shorter cells, cells of about the same length or even longer. Conidia formed singly, narrowly ellipsoid-cylindrical, 25–38 × 10–17 µm, on average < 15 µm wide, length/width ratio 1.6–2.5. Chasmothecia scattered to gregarious, 80–120 µm diam., subglobose to depressed-globose or almost hemispherical; peridium cells irregularly polygonal, 5–20 µm diam., wall of the cells up to 2.5 µm thick. Appendages numerous, equatorially arising and from the lower half, mycelioid, almost straight to usually sinuous or geniculate-sinuous, often strongly so, unbranched or occasionally irregularly branched, with short branchlets, 0.25–2 times as long as the chasmothecial diam. (up to about 220 µm), 3–9 µm wide, aseptate or only with few rather inconspicuous septa, at first hyaline, later pigmented, shorter appendages yellowish brown to medium brown throughout, longer ones brown below and paler towards the apex, tips subhyaline or hyaline, wall at first thin, later thin above and somewhat thickened towards the base, up to 2 µm thick, almost smooth to usually distinctly verruculose. Asci 3–10, broadly ellipsoid-obovoid, saccate, 40–75 × 25–40 µm, sessile to short-stalked, (3–)4–6(–7)-spored, ascospores ellipsoid-ovoid, 15–25 × 8–12 µm, colorless to yellowish.

Additional material examined: USA. Connecticut, Westville, Elm City Nursery, 29 Oct. 1907, G.P. Clinton (BPI 564441); without locality, 5 Nov. 1942, G.M. Reed (BPI 564442); Massachusetts, Wellesley, on leaves of *Baptisia tinctoria* (L.) R. Br., 14 Oct. 1884, C.E. Cummings (BPI 562107); Massachusetts, Andover, 6 Oct. 1924, E.W. Thompson (BPI 562196); New York, Rockland County, Nyack, 18 Aug. 1883, without collector (BPI 563594); Pennsylvania, Westmoreland County, New Florence, 8 Sep. 1907, D.R. Sumstine (BPI 562108); without locality and date, W.G. Farlow (BPI 562107).

Comments: *Erysiphe baptisiicola* is easily distinguishable from *E. baptisiae* by its much shorter, mycelioid (geniculate-sinuous), septate, pigmented chasmothecial appendages. This species belongs to the *Erysiphe pisi* complex, but it differs in having chasmothecial appendages without or with only few rather inconspicuous septa and walls that are thick-walled towards the base. Furthermore, the anamorph of *E. baptisiicola* is quite distinct by having conidiophores with curved-sinuous foot-cells and narrower conidia (foot-cells straight and conidia 24–55 × 13.5–22 µm, on average > 15 µm wide, in *E. pisi*, see Braun 1987, 1995).

## 4. A new species of *Erysiphe* on *Sesbania punicea*

***Erysiphe sesbaniae*** Wolcan & U. Braun, **sp. nov.** FIG. 3

MycoBank, MB 516546

Erysiphes robiniicolae *similis, sed cellulis basalibus conidiophorum brevioribus, 20–45 × (5–)6–9(–10) µm, appendicibus chasmotheciorum ubique crassitunicatis, ascosporis anguste ellipsoideis-ovoideis, interdum apice attenuato.*

ETYMOLOGY: derived from the host genus.

TYPE: ARGENTINA. BUENOS AIRES PROVINCE, La Plata, in a nursery, on leaves of young trees of *Sesbania punicea* (Cav.) Benth. (*Fabaceae*), Oct. 2009, N. Acosta (HAL 2330 F, **holotype;** LPS 48291, isotype).

MYCELIUM amphigenous, in white patches or effuse, often covering the entire leaf surface, thin to usually rather thick, persistent; hyphae branched, 2–7 µm wide, septate, hyaline, thin-walled, smooth to somewhat rough-walled. APPRESSORIA solitary, 3–10 µm diam., slightly to moderately lobed, occasionally almost nipple-shaped. CONIDIOPHORES arising from superficial hyphal mother cells, more or less terminal, in the middle or somewhat towards one end, erect, straight, up to about 80 µm long (without conidia), foot-cells 20–45 × (5–)6–9 (–10) µm, cylindrical, usually straight, occasionally somewhat sinuous, followed by 1–2(–3) shorter cells, sometimes followed by a single cell of about the same length. CONIDIA formed singly, primary conidia ellipsoid-ovoid, secondary conidia narrowly cylindrical or ellipsoid-cylindrical, 25–40 × 10–18 µm, length/width ratio 1.9–2.9, ends rounded to subtruncate. CHASMOTHECIA scattered to gregarious, (80–)100–140 µm diam., subglobose; peridium cells irregularly polygonal, 10–30 µm diam., walls of the cells up to 2 µm thick. APPENDAGES numerous, mostly about 10–15, ± equatorial and in the lower half, straight to often strongly sinuous-subgeniculate, simple, unbranched or apically irregularly to dichotomously branched, depending on age and developmental stage, 0.5–3.5 times as long as the chasmothecial diam. (up to about 350 µm long), 4–10 µm wide from base to top or somewhat narrower towards the apex, aseptate or 1–3(–4)-septate in the lower half, septa thin and often rather inconspicuous, hyaline or brown below and paler or colorless towards the apex, wall thick-walled from base to top or thinner towards the apex, up to 3 µm thick, rough-walled, often coarsely verruculose. ASCI 5–10 per chasmothecium, obovoid to saccate, 60–80 × 25–50 µm, short-stalked, wall up to 2.5 µm thick, terminal oculus relatively small, about 8–12 µm diam., (2–)3–4(–5)-spored, ascospores narrowly ellipsoid-ovoid, sometimes distinctly attenuated towards one end, (18–)20–28(–30) × 9–12 µm, colorless.

COMMENTS: *Erysiphe sesbaniae* belongs to a group of *Erysiphe* species that are characterized by having strongly sinuous-subgeniculate, thick-walled, distinctly, often coarsely verrucose chasmothecial appendages. The appendages are simple, unbranched or apically irregularly to dichotomously branched,

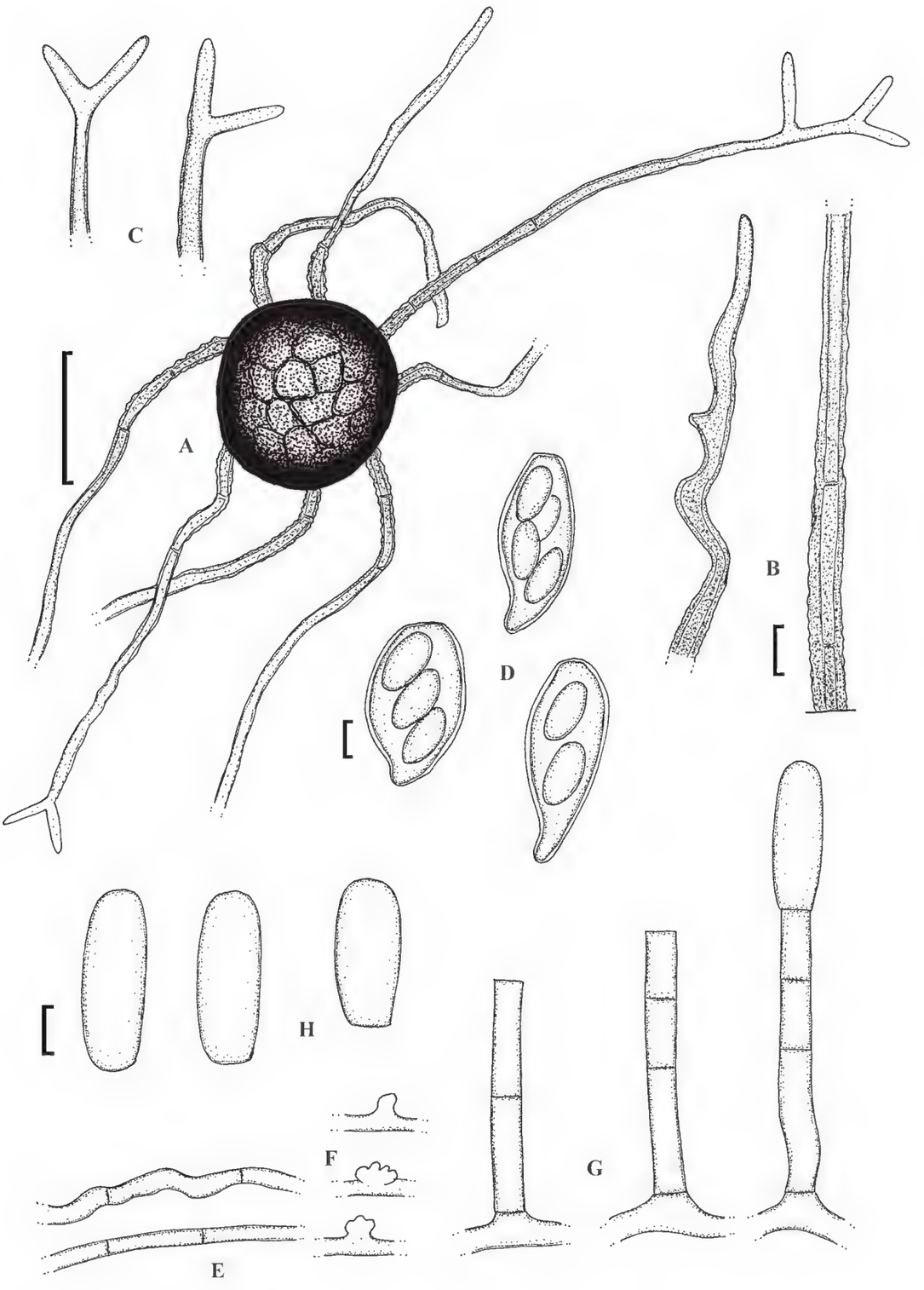


Fig. 3. *Erysiphe sesbaniae* (based on type material).
A. Chasmothecium. B. Base and apex of an appendage. C. Tips of appendages.
D. Asci. E. Hyphae. F. Appressoria. G. Conidiophores. H. Conidia.
Scale bars = 100 µm (A), 10 µm (B–H). U. Braun del.

depending on age and developmental stage, rendering the species concerned morphologically intermediate between *Erysiphe* sect. *Erysiphe* and *Erysiphe* sect. *Microsphaera*. The following species, almost all from Asia, belong to this group: *Erysiphe bremeri* U. Braun on *Alhagi* and *Sophora* spp.; *E. crispula* (U. Braun) U. Braun & S. Takam. on *Astragalus* (Asia and North America), *E. hedysari* (U. Braun) U. Braun & S. Takam. on *Hedysarum* spp. and *Anthyllis maura* Beck; *E. thermopsidis* R.Y. Zheng & G.Q. Chen [= *Microsphaera thermopsidis* U. Braun (≡ *E. shinii* U. Braun & S. Takam.)] on *Thermopsis* spp.; and *E. robiniicola* U. Braun & S. Takam. [≡ *Microsphaera robiniae* F.L. Tai, non *Erysiphe robiniae* Grev.] on *Robinia* spp. (Braun 1987, Braun & Takamatsu 2000, Braun et al. 2009, Liu & Braun 2009). *Erysiphe robiniicola*, known from China on *Robinia hispida* L. and *R. pseudoacacia* L., is morphologically close to *E. sesbaniae*, but it differs in having conidiophores with longer foot-cells, 30–65 µm, appendages thick-walled below and thin-walled towards the apex, and broadly ellipsoid-ovoid ascospores, 15–22 × 9–14 µm, which are never distinctly attenuated towards one end (Braun et al. 2009). *Robinia* and *Sesbania* are two related genera that cluster together in the robinioid clade [*Robinieae*] (Wojciechowski et al. 2004). There are numerous records of powdery mildew on various *Sesbania* spp. under different names, e.g. *Erysiphe communis*, *E. polygoni* and *Oidium* sp. (Amano 1987). The identity and relation of these records to *E. sesbaniae* are unclear.

## 5. Key to the species of the *Erysiphe bremeri* / *E. pisi* / *E. trifoliorum* complex on legumes

1. Chasmothecia only with 1–4(–7) appendages, 0(–3)-septate, apex occasionally 1(–2) times branched; on *Pueraria*, China. . *E. puerariae* R.Y. Zheng & G.Q. Chen

1* Chasmothecia with numerous appendages ..... 2

2. Chasmothecial appendages mycelioid (geniculate-sinuous), about 0.5–3 times as long as the chasmothecial diam., equatorially arising and from the lower half, unbranched or irregularly branched ..... 3

2* Chasmothecial appendages either apically at least partly dichotomously branched and/or appendages not mycelioid, straight to flexuous, and very long, 3–10 times the chasmothecial diam. ..... 13

3. Appendages rather short, 0.5–1(–2) times as long as the chasmothecial diam., hyaline or only faintly yellowish, 0–1(–2)-septate, thin-walled, usually curved, "spider-like;" on *Genista*, *Melilotus* and *Thermopsis*, Asia, Armenia ..... *E. thermopsidis*

3* Appendages not characteristically curved, not "spider-like" ..... 4

4. Appendages frequently irregularly branched or even branched in a coral-like manner ..... 5

4* Appendages usually unbranched, only occasionally irregularly branched ..... 6

5. Appendages frequently and strongly branched, hyaline to yellowish, aseptate or only with 1–2 inconspicuous septa; on *Lathyrus* and *Vicia* in Asia ..... *E. viciae-unijugae* (Homma) U. Braun

5* Appendages moderately branched, brown throughout or at least in the lower half, thin-walled, conspicuously pluriseptate; on *Lathyrus* and *Ononis*, Europe ..... *E. pisi* var. *cruchetiana* (S. Blumer) U. Braun

6. Chasmothecia large, (100–)110–185(–210) µm diam., confined to stems, appendages narrow, 3.5–7 µm wide, fairly thick-walled throughout, aseptate or only with few inconspicuous septa; on *Astragalus*, Asia, Europe ..... *E. caulicola* (Petr.) U. Braun

6* Chasmothecia smaller, and/or appendages thin-walled, distinctly pluriseptate, not confined to stems ..... 7

7. Chasmothecial appendages at least thick-walled towards the base, aseptate or only with few rather inconspicuous septa, verruculose ..... 8

7* Chasmothecial appendages thin-walled, distinctly pluriseptate, smooth or only faintly rough-walled ..... 9

8. Chasmothecia 90–120 µm diam., appendages brown throughout or brown below and paler towards the tip when mature, usually unbranched, only occasionally irregularly branched, with short branchlets; on *Baptisia* spp., North America ..... *E. baptisiicola*

8* Chasmothecia large, 90–180 µm diam., appendages colorless or only faintly pigmented at the base, rather narrow, 3.5–8.5 µm, at first unbranched, but apex always irregularly to dichotomously branched when fully mature (on *Anthyllis* and *Hedysarum*, Asia and Europe, see immature samples of *E. hedysari*) or appendages 5–10.5 µm wide, causing deformations and defoliations of the hosts (on *Alhagi* and *Sophora*, Asia, see immature samples of *E. bremeri*)

9. Chasmothecia small, 65–100(–110) µm diam., asci 2–7-spored, ascospores small, 14–20 × 9–13.5 µm; on *Cercis*, China ..... *E. cercidis* T. Xu

9* Chasmothecia and ascospores larger ..... 10

10. Asci with 2–4 rather large ascospores; conidiophores with short, straight foot-cells, 20–30 µm long; on *Hoffmannseggia*, South America, Argentina ..... *E. deserticola* Speg.

10* Asci (2–)3–8-spored; foot-cells of the conidiophores longer or curved-sinuous; on other hosts ..... 11

11. Chasmothecia scattered to usually gregarious, appendages pigmented, at least brown in the lower half, 4–10 µm wide, asci 3–5(–6)-spored; foot-cells of the conidiophores straight; on *Pisum* and numerous other hosts, worldwide ..... *E. pisi* var. *pisi*

11* Chasmothecia characteristically (regularly) scattered, appendages colorless or only faintly pigmented, yellowish, narrow, (2–)3–6(–8) µm wide, asci 4–8-spored; foot-cells of the conidiophores curved-sinuous; on *Amphicarpaea*, *Desmodium*, *Glycine*, *Lespedeza* ..... 12

12. Asci 4–7-spored, mostly 5–6-spored; on *Amphicarpaea*, *Desmodium*, *Glycine*, North America and Asia ..... *E. glycines* F.L. Tai

12* Asci 6–8-spored; on *Lespedeza*, Asia ..... *E. lespedezae* R.Y. Zheng & U. Braun

13(2*) Appendages short, 0.5–4 times the chasmothecial diam., strongly sinuous-geniculate, contorted, apex often simple, branchings rarely developed, wall mostly thickened and verruculose; on *Alhagi*, *Anthyllis*, *Genista*, *Hedysarum*, *Robinia*, *Sophora*, *Thermopsis*, Asia and Europe, or *Sesbania*, South America ..... 14

13* Appendages very long, mostly 3–10 times the chasmothecial diam., when relatively short, appendages rather stiff, not mycelioid; on other host genera and also on *Sophora* ..... 18

14. Mycelium dense, persistent, causing deformations and defoliations, "witches' brooms;" on *Alhagi* and *Sophora*, Asia ..... *E. bremeri*

14* Mycelium amphigenous and caulicolous, subpersistent, without deformations or defoliations; on other host genera ..... 15

15. Chasmothecia large, (95–)110–170(–180) µm diam., appendages 5–20, narrow, 3.5–8.5 µm wide, tips in fully mature samples often recurved, appendages in mature samples strongly rough-walled; on *Anthyllis maura*, *Hedysarum* spp., Asia and Europe ..... *E. hedysari*

15* Chasmothecia smaller, about 80–140 µm diam., appendages wider, up to about 10 µm, tips straight; on other hosts ..... 16

16. Appendages very numerous, 10–40, mostly more than 20, faintly rough-walled; on *Genista*, *Melilotus*, *Thermopsis*, Asia, Armenia ..... *E. thermopsidis*

16* Appendages less numerous, about 6–25, mostly 10–20, distinctly rough-walled, often coarsely verruculose ..... 17

17. Asci (4–)5–6(–7)-spored, ascospores small, 14–20 × 10–15 µm; foot-cells of the conidiophores 30–65 µm long; on *Robinia*, China ..... *E. robiniicola*

17* Asci (2–)3–4(–5)-spored, ascospores larger, 20–28 × 9–12 µm; foot-cells of the conidiophores shorter, 20–45 µm; on *Sesbania*, South America ..... *E. sesbaniae*

18(13*) Appendages either ± horizontally spread, septate and pigmented, at least up to the middle of the stalk, or appendages with a tendency to turn towards one direction, aseptate or 1(–2)-septate, hyaline or only pigmented at the very base, flexuous, but not mycelioid, most appendages simple, only a varying percentage apically 1–3 times branched in fully mature samples, branchings diffuse, wide (*E. trifoliorum* complex: *E. astragali*, *E. baeumleri*, *E. baptisiae*, *E. intermedia*, *E. trifoliorum*) ..... 19

18* Appendages mycelioid, irregular, sinuous-geniculate (on *Astragalus* or *Spartium*), apex frequently dichotomously branched ..... 24

19. Appendages frequently branched in mature samples, with a moderate tendency to turn towards one direction, tips of the ultimate branchlets straight; on *Vicia*, North America, Asia, Europe ..... *E. baeumleri*

19* Branched appendages rare; on other host genera ..... 20

20. Appendages mostly with a conspicuous tendency to turn towards one direction, sometimes even subfasciculate, tips of the ultimate branchlets in fully mature samples often recurved; on *Astragalus* and *Oxytropis* ..... *E. astragali*

20* Appendages horizontally spread, tips of the ultimate branchlets straight to somewhat curved or appendages only with a slight to moderate tendency to turn towards one direction and tips straight; on various other host genera ... 21

21. Chasmothecia small, 70–90(–105) µm diam., appendages evidently verrucose, at least below, caulicolous; on *Desmanthus*, USA ..... *E. desmanthi*

21* Chasmothecia larger, on average > 90 µm, appendages smooth to verruculose towards the base; on other hosts ..... 22

22. Foot-cells of the conidiophores usually curved to flexuous, sinuous; appendages horizontally spread, aseptate, colorless; on *Baptisia*, Europe ..... *E. baptisiae*

22* Foot-cells of the conidiophores usually straight, only occasionally slightly curved or sinuous; appendages either septate and pigmented below the septa or with a tendency to turn towards one direction ..... 23

23. Appendages 0–1-septate, hyaline or only pigmented at the very base, often with a slight to moderate tendency to turn towards one direction; on *Lupinus* ..... *E. intermedia*

23* Appendages 0–6-septate, pigmented at least in the lower half, usually horizontally spread; on *Trifolium* and hosts of various other genera ..... *E. trifoliorum*

24(18*) Appendages smooth to faintly rough-walled, branchlets of different orders frequently recurved, flexuous to curled, tips mostly recurved to almost spirally coiled; on *Astragalus*, Asia, North America ..... *E. crispula*

24* Appendages evidently verrucose, only primary branches sometimes recurved, tips straight to partly recurved; on *Spartium*, Mediterranean region ..... *E. rayssiae*

## Acknowledgements

We are much obliged to A.M. Minnis (USDA, ARS, Systematic Mycology and Microbiology Laboratory, Beltsville, USA) and H.D. Shin (Korea University, Division of Environmental Science and Ecological Engineering, Seoul, Korea) for providing pre-submission reviews and to the curators of BPI, LPS and STR for the possibility to examine collections deposited in these herbaria.

## Literature cited

Amano K. 1986. Host Range and Geographical Distribution of the Powdery Mildew Fungi. Japan Scientific Societies Press, Tokyo.

Braun U. 1984. Descriptions of new species and combinations in *Microsphaera* and *Erysiphe* (V). Mycotaxon 19: 375–383.

Braun U. 1985. The *Erysiphe–Microsphaera* complex on *Fabaceae*. Zentralblatt für Mikrobiologie 140: 398–417.

Braun U. 1987. A monograph of the *Erysiphales* (powdery mildews). Beihefte zur Nova Hedwigia 89: 1–700.

Braun U. 1995. The powdery mildews (*Erysiphales*) of Europe. G. Fischer Verlag, Jena.

Braun U, Cook RTA, Inman AJ, Shin H-D. 2002. The taxonomy of the powdery mildew fungi. 13–55, in R Bélanger et al. (eds.): The powdery mildews: a comprehensive treatise. St. Paul, APS Press.

Braun U, Kummer V, Xu B. 2009. Taxonomy and nomenclature of powdery mildew fungi: *Erysiphe asclepiadis*, *E. robiniicola* and *Golovinomyces caulicola*. Mycotaxon 107: 285–295.

Braun U, Takamatsu S. 2000. Phylogeny of *Erysiphe*, *Microsphaera*, *Uncinula* (*Erysipheae*) and *Cystotheca*, *Podosphaera*, *Sphaerotheca* (*Cystotheceae*) inferred from rDNA ITS sequences – some taxonomic consequences. Schlechtendalia 4: 1–33.

Eliade E. 1990. Monografia Erysiphaceelor din România. Lucrările Grădinii Botanice din Bucureşti 1989–1990: 105–574.

Heluta VP. 1998. Distribution of *Erysiphe* and *Microsphaera* species (*Erysiphales*) by phylogenetic groups of legumes. Ukrayins'kyi Botanichnyi Zhurnal 55: 481–486.

Holmgren PK, Holmgren NH, Barnett LC. 1990. Index herbariorum, Part. 1: The Herbaria of the World. 8th edn. Regnum vegetabile 120: 1–693.

Liu T, Braun U. 2009. Taxonomic notes on some powdery mildews from Inner Mongolia. Mycotaxon 109: 21–27.

Mayor E. 1968. Champignons observes à Neuchâtel dans les jardins de l'Institut de botanique de l'Université. Bulletin de la Société Neuchâteloise des Sciences Naturelles 91: 43–54.

Mori Y, Sato Y, Takamatsu S. 2000. Evolutionary analysis of the powdery mildew fungi using nucleotide sequences of the nuclear ribosomal DNA. Mycologia 92: 74–93.

Saenz GS, Taylor JW. 1999. Phylogeny of the *Erysiphales* (powdery mildews) inferred from internal transcribed spacer ribosomal DNA sequences. Canadian Journal of Botany 77: 150–168.

Wallroth FW. 1819a. Naturgeschichte des *Mucor Erysiphe* L. Verhandlungen der Gesellschaft Naturforschender Freunde zu Berlin 1: 6–45.

Wallroth FW. 1819b. De Mucore Erysiphae Linnaei. Annalen der Wetterauischen Gesellschaft für die Gesammte Naturkunde 4: 226–247.

Wojciechowski MF, Levin M, Sanderson MJ. 2004. A phylogeny of legumes (*Leguminosae*) based on analysis of the plastid matK gene resolves many well-supported subclades within the family. American Journal of Botany 91: 1846–1862.